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1. Your reference — Veri 10 114593

2. Patent application number *(The Patent Office will fill in this part)* — 30 NOV 2002 — 0228081.6

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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   Veritasveien 1
   N-1322 HOVIK
   NORWAY

   Patents ADP number *(if you know it)* — 08518987001

   If the applicant is a corporate body, give the country/state of its incorporation — NORWAY

4. Title of the invention — MARINE VESSEL, LAYERED STRUCTURE FOR USE IN VESSELS, LAYERED STRUCTURE MODULE, ELEMENT FOR FORMING A LAYERED STRUCTURE MODULE AND METHODS FOR FORMING A LAYERED STRUCTURE

5. Name of your agent *(if you have one)*

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   Patents ADP number *(if you know it)* — 08273419002

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DUPLICATE

Marine vessel, layered structure for use in vessels, layered structure module, element for forming a layered structure module and methods for forming a layered structure

The invention relates to a marine vessel, a layered structure for use in a marine vessel, a layered structure module, an element for obtaining a layered structure module, and methods for producing the layered structure.

Most commercial and military ships today, with the exception of fast going surface effect ships, have a hull that is made purely of steel plates. The steel plates have two main functions, namely to serve as a water tight membrane against the sea and thereby provide buoyancy, and, second, to provide strength capacity needed for carrying environmental loads and loads from cargo, other functional loads etc. Structural steels may have very high strength, however, it is difficult to exploit the strength capacity fully because thin steel plates may suffer buckling in compression. The traditional way of increasing the buckling capacity of steel plates is to connect the plates with beams and frames, and to attach stiffeners in on or two directions as a plate field grid stiffening. Highly stressed corners and other details often are strengthened with additional bracings or supporting elements. For bulkheads which form separation walls between cargo holds in a ship an alternative stiffening principle is to form the wall plating with a channel-type corrugation and thereby achieving increased carrying capacity and stiffening for transverse loads. However, it must be realized that also corrugated plates may display severe forms of buckling even for transverse loading.

Looking at a typical steel ship design one is easily struck with the complexity and the many different structural members a ship is constructed from. In fact, for a large ship there may be as many as 100 000 steel pieces welded together to form the ship hull structure. This complexity is not only a matter of cutting and fitting together many pieces of steel, but, more importantly, it implies that highly extensive and expensive welding work has to be carried out. Welds between plates and stiffening elements are also critical zones for fatigue and fracturing. These welds, in addition to general corrosion, are the main factors determining the service life of a ship.

Another important design consideration for hull structures is their capacity for sustaining extreme and accidental loads. In this context three matters are particularly significant, namely the capability of absorbing energy from the accidental loads, the capability of redistribution of loads through structural redundancy, and the capability of maintaining water and cargo tightness in a damaged condition. In later years there have been introduced new national and international regulations to this end. For example, double hull design, i.e. double barriers between the oil tanks and the sea, has become mandatory for new tank

ships. There is of course additional steel usage and costs associated with most of these new ship hull requirements, however, this is a price that safety demands.

New measures, as those described above, may also have implications beyond the problems that they are intended to deal with in the first place. The open space between the skins in a double hull is often used for storage of ballast water or fuel. These spaces with the plate field grid stiffening are often difficult to inspect and to clean. This has implications for detecting and repairing damage as well as it may be a source for contaminating ballast water.

There exist alternative ways of achieving enhanced safety and environmental performance including improved strength, collision resistance, reduction of stress concentrations where cracks may begin, reduced corrosion exposed surfaces, better cleaning of compartments, etc. For instance, it is known that relatively light and strong plate structures or structural components can be achieved through composite or "sandwich" plate construction. Composite plates and shells are extensively used in the field of aerospace, particularly with fibre reinforced plastics used in the surface skins and foam or "honeycomb" core materials.

Composite hulls and plate panels have also been used for ships. For instance, glass fibre reinforced plastic skins with foam plastic core or elastomers have been used for hull construction for small and moderately large, high speed light crafts. Composite panels have been used as separation walls and floors in the interior of ships. However, current regulations, such as SOLAS, may prevent use of highly combustible materials such as plastics from being used in large passenger vessels. It is also a fact that large ships built in such a way would be both rather expensive and may exhibit deformation beyond what normally would be acceptable. Another well known problem with plastic skin and foam designs for hulls is that there is a tendency for "delamination", i.e. separation between skins and core, during high intensity surface loading. This may severely damage the load carrying capacity and integrity of the hull.

From the discussion above it is evident that plastic skin-core composite construction is not attractive for building large ship hulls. However, composite plate design is in principle structurally very efficient.

Earlier there have been made attempts to build marine vessels where the main part of the vessel comprises concrete and metal sheets. One example of this is given in US 1,240,129. In this example there is an outer, an intermediary, and an inner metal sheet and concrete filled in between the inner and the intermediary metal sheet. The only specification for the concrete to be used is that it is preferably of such a consistency that it may be poured into the space between the two sheets.

There are also other applications where concrete has been used in connection with marine vessels.

One other example is the marine use of the double skin composite panels described in US patent 5,741,571. The double skin panel comprise two steel facing plates joined together by a plurality of cross-members. A filler material, e.g. concrete is thereafter introduced into the spacing between the facing plates. The facing plates are prefabricated fastened together by the coss-members and delivered to building site without the concrete filling. The panels are put together with special mechanical devices. The concrete is poured into the void in between the facing plates after assembly. There are not set any requirements regarding the concretes properties. This double skin panels are in advertising suggested used for circular legs of semi-submersibles, suction anchor piles or submerged tube tunnels. The arguments for using this system are the lightweight of the facing plates when they are transported to the building site and the strength they give to the construction. It should be noted that typical concrete for this concept would be standard or normal concrete or in special cases light weight concrete as for instance used offshore in the North Sea which concrete has a weight of 1900 kg/m^3.

Concrete has also been used for other purposes in relation to marine structure. One use is in connection with strengthening a hull of a ship. One example of this is given in the publications SU 1646944, where one uses a cement adhesive layer on the metal hull, a layer of spiral wire netting embedded in a filler concrete layer which is limited by another layer of reinforced netting which on top has a coating layer of cement. Another example for strengthening a hull is given in US 6,009,821 where the hull of a tank ship is provided with a double hull requiring essentially no internal steel structural support by distributing and compacting sand in the bottom of the tank or cargo hold, applying a layer of reinforced concrete to the sand, laying steel plates on the surface of the cured concrete and welding the abutting edges of the plates to the hull. This example can only efficiently be used for the bottom of a hull in a ship, and gives no solution for the bulkheads or the side structures. Both these procedures also consist of several steps and are, due to this, quite extensive in workload when executed.

A method more or less equal to these is also described in FR 2 478 015. It is descried that concrete is applied to areas where a metal sheet in contact with water should be repaired or improved. The concrete preferably has a specific weight of less than 1 and is applied in a layer of between 5 and 45 centimetre. The concrete layer may be armoured and there may be applied another tight layer in addition to the concrete.

These solutions are for repairing or improving the structures of an existing ship, which already have a steel structure that is dimensioned for the forces that a ship

may be exposed for. The requirements for both the steel sheets and the concrete use in these solutions will be significantly different from the requirements of the current invention where the whole ship hull, or parts of the ship, are built step by step and in assemblages of small and large structural modules, with a layered structure.

The main purpose for the present invention is to achieve a new way for constructing the whole or part of a marine vessel with a layered structure, a layered structure suitable for use in vessels or other structural constructions, and a method to produce such composite structures, which is competitive with traditional vessel design.

Another main purpose of the present invention is to provide a vessel where the different parts of for instance the hull have strength and stiffness properties which improve the integrity and overall performance in case of accidental loading, such as explosions, collision and grounding, in comparison with traditional single and double skin ship hull design, and to provide a vessel which has a improved safety against being wrecked compared with ordinary ships. Another aim is to provide a layered structure for use in for instance ships, which has enhanced environmental performance compared with ordinary single and even ordinary double hull ships. This refers to integrity and resistance against leakage of damaging cargos or fuels as well as the way ballast water may be dealt with in the ships structure.

A further aim is to provide a layered structure for use in ships that is advantageous as means for reducing the overall exposed surface area so that it becomes smooth with minimal corners and connections, so that emptying, cleaning and maintenance becomes easier, more efficient and thereby less costly. The overall area that needs corrosion protection is thereby also reduced. It is also an aim to provide a layered structure for use in ships that has good fire insulation properties and overall very beneficial fire behaviour, and also have good properties in reducing noise and vibrations.

A further aim is to develop a layered structure that can be used for designing a whole vessel that will be economically competitive with conventional steel ships and that results in increased safety at sea. To achieve a layered structure with the necessary strength and stiffness properties, which at the same time uses significantly less steel and may be lighter than an equivalent steel structure for a ship is another aim. Finally, is it a goal to achieve a ship that is significantly less prone to fatigue cracking than a conventional ship, thereby reducing the need for maintenance and repairs, and resulting in enhanced design life.

These aims are achieved with a vessel, a layered structure and a method in accordance with the following claim.

The invention regards a marine vessel, such as ships, floating platform etc, where the whole or part(s) comprises a layered structure and a layered structure including

two substantially parallel metal sheets with a concrete layer in between, where the concrete has density significantly less than that of normal concrete, preferably less than about 1200 kg/m^3, where the layered structure is dimensioned as if the concrete layer in the structure can carry substantially no tension but is capable of carrying compressive forces.

A marine vessel may be any type and size of ships, for instance a bulk carrier, a tanker or a container ship or a barge or other types of boats. A marine vessel may also be a semi-submersible platform with or without propulsion devises or other seagoing structures. The marine vessel may be built totally with a layered structure in accordance with the invention or parts of the vessel may comprise a layered structure, for instance may the hull and bulkheads comprise a layered structure but the hopper tanks and the wing tanks may be formed with steel plates connected to the layered structure hull and bulkhead. Another possibility might be to have just the outer hull with a layered structure, or only parts of the hull with a layered structure like the parts around the engine room. The layered structure comprises two metal sheets with a concrete layer in between. The concrete in the concrete layer may be denoted as an ultra lightweight concrete (ULWC) when it has density less than 1200 kg/m^3 which is half of that of normal concrete, which has a weight of about 2300 to 2500 kg/m^3. The concrete layer in the layered structure is, when dimensioning the layered structure, assumed not to be able carry significant tension forces, and to transfer all the perpendicular pressure forces in the layered structure.

The outer layers of the layered structure may be made of any type of metal approved for ship applications by Classification Societies or other appropriate authorities. This includes typical ship plates made with steel qualities like "Normal Strength Steel" (NS) with minimum yield stress of 235 MPa, "High Strength Steel" (HS) with minimum yield stress of 265 MPa up to and including 390 MPa, and "Extra High strength Steel" (EHS) with minimum yield stress of 420 MPa up to and including 690 MPa. There exist a very large number of specific steel notations that fall within these classes of steel quality. Special alloys like austenitic and duplex stainless steel may also be used. Moreover, for special applications in a ship one may use so-called clad steel plates consisting of a base material and a thinner layer (cladding metal) on one or both sides, continuously and integrally bonded. Other metals like aluminium and titanium may also be used as long as they display sufficient compatibility with the structural and chemical behaviour of the light weight concrete core material.

The core material, the concrete layer, comprises of a material which displays appropriate mechanical, chemical and other functional properties to be suited for the proposed invention. The preferred material is a ultra light weight concrete (ULWC) with weight less than half that of normal concretes which typically weighs about

2400 kg/m^3, that is, ULWC with density less than 1200 kg/m^3 should normally be aimed for. It is to be noted that such ultra light weight concretes are significantly different from light weight concretes that earlier have been used for example for offshore structures in the North Sea, and which have a weight of approximately 1900 kg/m^3.

The composition of ULWC is significantly different from that of normal concretes. To make such concretes one may use light weight aggregates in the concrete mix, such as expanded shale, clay, vermiculite, pumice (foam lava), scoria, foam glass, foam plastic, etc. There are many types of commercial light weight aggregates available. Alternatively, special chemicals may be added to obtain a large content of air or gas bubbles in the concrete mix. Combinations of light weight aggregates and air or gas bubbles may also be used. One may also add various types of fibres reinforcement to enhance the ductility and tension strength of the concrete.

To achieve good structural concretes with very low weight is rather demanding. A series of such concretes for use in the present invention has been developed and tested. The mix designs included use of water, different types of cements, silica, limestone filler, aggregates like "Liaver", "Poraver", "Perlite", "Leca", and various types of chemical additives. As an example, one of these types of concrete characteristically had fresh concrete density of 905 kg/m^3, compression cube strength of 14.5 MPa, splitting tensile strength of 2.6 MPa, and Youngs moduls (E-modulus) of about 6000 MPa. This shows that ultra light weight concretes with sufficient strength to serve in the present invention can be obtained. The same mix also has good workability properties for placing in the composite plate structure.

The strength and structural integrity of the present invention not only depends on the properties of metal and concrete, but equally much on the interactive behaviour between these materials. As for normal steel ships the primary part of the strength comes from the carrying capacity of the steel. The placing of most of the metal in the layered structure at the two surfaces is an optimum solution to give the structure bending stiffness and prevent component buckling. Although the concrete in reality has some tension strength, and, in fact, the ratio between tension and compressive strength for the tested ultra light weight concretes has proved to be higher than for normal concretes, it should conservatively be assumed for design and dimensioning that the concrete does not carry significant tension forces. However, the concrete in the composite plates and walls still has several important functions:

a. To supply compressive strength and stiffness for the overall structure
b. To support the surface steel plates against buckling

c. To provide a series of other functional properties for the composite structure, such as capability of absorbing energy under catastrophic loads, fire resistance, structural damping, etc.

To enhance the concrete layers structural strength there may be added fibres into the concrete mix. The length, density and direction of the fibres may be adapted to the specific use.

Utilization of the compressive strength and stiffness capabilities of the concrete for the overall structure is rather straight forward as long as deformations and stresses are kept within requirements set by appropriate design codes (Eurocode etc.).

The function of supporting the surface metal sheets against buckling is also highly important. A conservative approach should be taken; that is, the actual design should not rely upon full bonding between concrete and metal. Resistance against separation and surface plate buckling outwards can be achieved through connectors between the sheets in the layered structure and/or dowels from one sheet into the concrete layer, in appropriate locations and with appropriate spacing between them. The concrete provides support against rotations at these anchoring points such that the holding of the surface sheet is nearly "fixed" at these points and, thereby, increases the buckling capacity of the surface sheet. The buckling capacity of the surface sheets with such fixing points can be calculated with appropriate design formulas, thereby ensuring there is sufficient capacity against buckling failure for all design conditions. In this connection it is also to be noted that surface sheets that are fixed in this way have very significant post-buckling, reserve carrying capacity that contributes towards the overall safety of the concept.

A major advantage with a layered structure where the space between the metal sheets is filled with concrete is that the buckling failure that has been the cause of many shipwrecks is no longer the most critical failure mode. The hull beams may, with a layered structure in accordance with the invention be made stiffer, and by this, become more compatible with the stiff hatch structures which are designed in accordance with the Post Derbyshire requirements. This gives a more uniform stiffness for the different part of a ships structure. The design improves properties in connection with explosion, collision and grounding because the concrete is a good barrier for energy absorption and distribution of contact forces. The robust bulkheads and possible double bottom structure reduces local damage on the structure from cargo handling equipment.

Other important functional properties of the composite structure can be quantified through analysis of the specific designs and through laboratory testing.

In cases where it is necessary to increase the bonding between the metal and the concrete the surface of the metal sheet that is faced towards the concrete layer may either have increased roughness in the surface, be treated with a roughening or an adhesive layer, be equipped with dowels, or have a combination of these different means.

The dowels may be of several forms and may just reach a small distance into the concrete layer or they may reach almost to the other side of the concrete layer. The dowels may be welded, bolted or in other manner glued or fastened to the surface of the metal sheet.

In between the metal sheets in the layered structure there is at least one connector. The purpose of the connectors is to transfer loads between the metal sheets in the layered structure, and they also function as reinforcement in the layered structure. The connectors may be in the form of point connectors or it may have an extension in one or several direction, as for instance a plate girder. Preferably there are in the layered structure connectors in form of girders in one direction combined with point connectors in between the girders. The type and amount of connectors, point connectors or girders, will depend on the specific use of the layered structure, there are different requirements to a hull compared with a bulkhead, in relation to strength for instance against buckling.

The layered structure's concrete layer may include closed channel elements. These channels elements are in general open in both ends and have internal voids. Together with other part of the structure they may form closed voids, a box, here also denoted "spar-boxes". The channel elements are included in the concrete layer to both increase the total strength of the layered structure and also reduce the weight of the layered structure. The channel elements are connected to the adjacent metal sheets in the layered structure with spacers. The spacers can have several forms, like I-beams, U-shaped hooks or others, and they may be welded, slid, bolted or jammed into a fixed connection with both the channel element and the metal sheet. The spacers have several functions, such as to prevent surface metal sheets to buckle, transfer shear forces, as elements for transferrals of loads, and during production to hold eventual spar-boxes in the right position.

The open ends of the channel elements may be connected to adjacent metal walls in the end of the layered structure or girders in the layered structure. The connection may be done by welding the channel element to for instance girders, and then there is formed an enclosed spar-box. This spar-box is normally closed, but there may be accesses to the void so that the spar-box can function as a service shaft or inspection shaft, storage of water or fuel or other liquids, or similar.

In case of designing new vessels or replacing parts of an existing vessel one may design for instance the bulkheads with a layered structure in accordance with the

invention, and simultaneously dimension the spar-boxes in the layered structure so that they may function as compartments for ballast water with the required safety and access through piping and possibly also manual accesses. In other cases the layered structure for a part of a vessel may be designed so that the spar-boxes in the layered structure can function as fuel compartments.

The layered structure is normally made with metal sheets of normal steel used in shipbuilding, as mentioned earlier, but in some cases is the content that is supposed to be transported inside a cargo hold or compartment or even a spar-box, of a type that attack or corrode normally used steel. In these cases may the layered structure include an outer layer of a different material that is more resistant toward the material to be transported. Such plates are often referred to as clad plates. An example is if the material to be transported is highly corrosive then the layered structure may include an outer layer of stainless steel. This may be economically feasible in the case of cargo holds or tanks in accordance with the invention since the holds have smooth sides and the amount of stainless steel to cover the hold because of this will be at a minimum. Other ways of protecting the steel through painting or application of protective layers of suitable materials may also be used.

Regarding production, use and maintenance there are several factors that will be influenced by a layered structure in accordance with the invention for the whole or parts of a vessel compared with a normal steel structure in for instance a bulk carrier. The welding volume of the hull structure can, with a layered structure in accordance with the invention, be reduced by as much as 50% compared with a double hull steel carrier. The hull structure can be built from fever pieces and a greater percentage of pieces may be prefabricated.

Extensive work has been carried out to verify the feasibility of the current invention. This includes design and analysis of bulk carrier ships of so-called Panmax type. All major loading and design requirements of a Classification Society have been considered in this verification. Numerical analyses with use extensive finite element models for concrete and steel were carried out. The study has proven that ships may be built according to the current invention with significantly less use of steel and welding than for conventional ships. Moreover, it has been shown that such ships even may weigh the same or less than for equivalent double hull steel ships. Ships designed and built in accordance with the current invention also have a series of other beneficial properties including being price competitive.

It is a major benefit to achieve a hold in a bulk carrier, container ship or tanker with smooth sides and a minimum of corners, as one can achieve with the layered structure in accordance with the invention. The smooth sides allows for easy, more speedy and more environmentally friendly cleaning, which will give an economic benefit with both less use of chemicals, workmen and down time for the vessel due

to the cleaning operation. A smooth cargo hold tank may also give the possibility of using the same cargo hold for both cargo and ballast water since the cleaning may be done properly. The smooth sides of the bulkheads and the hulls etc. also reduces cost in relation to maintenance, both due to the reduced area that have to be coated for protection against corrosion but also due to the fact that there are less areas exposed to corrosion, and less areas that have to be checked during inspection and maintenance procedures.

The layered structure in accordance with the invention gives improved performance in case of fire, since the concrete has good fire protection capacity. One may also embed the piping necessary on the ship in the concrete layer of the layered structure or in the voids in the concrete structure and thereby avoid, prevent or at least limit corrosion and enhancing fire protection.

The layered structure in accordance with the invention may as it is described above consist of a compact layered structure with two sheets of metal and an intervening layer of concrete with weight preferably below 1200 kg/m^3. This compact structure may be considered to be similar to a double hull structure in it self due to the fact that the layered structure have two sheets of metal in the structure, and in addition has a core material of importance for collision and grounding performance.

The invention also includes a layered structure module for use in for instance a vessel such as a ship, a floating platform or similar or other structural constructions. The layered structure module is in accordance with the layered structure in claims 2-12, and is constructed of at least two smaller elements with a thickness mainly equal to the modules thickness, and that the elements in addition may comprise at least one connector between the two metal sheets. The smaller elements may have a length mainly equal to the modules length, and a width mainly equal to a part of the modules other length perpendicular to the first. To form a whole or a part of a vessel several modules which may have different or similar form may be put together. Some modules may first be assembled together, which modules thereafter are connected to form modules of another level which again are attached together with other combinations of modules to form another level of modules.

In addition the invention also includes an element for obtaining a layered structural module, where the element comprises two substantially parallel metal sheets with a concrete layer in between, where the concrete has density substantially less than for normal concrete, preferably less than about 1200 kg/m^3. The element has a length, a width and a thickness, where the thickness and length mainly corresponds to the layered structure module and the width amount to a part of the layered structural module. In one embodiment the element may have at least on one edge an open channel element in the concrete layer, mainly parallel to the metal sheets. This

channel element forms at least a part of a closed channel element in the concrete layer, when two elements are joined together.

The invention also comprises methods in relation with the layered structure. For producing a layered structure for building of whole or parts of a vessel such as ships, floating platform or similar, a method may comprise the use of two mainly parallel metal sheets, where the metal sheets are positioned in a wanted distance, and that in between these two sheets is injected an intervening layer of concrete, which concrete has a density less than for normal concrete, preferably less than about 1200 kg/m^3.

Method for producing an element for forming a layered structure for building of whole or parts of a marine vessel uses pairs of mainly parallel metal sheets, where the metal sheets are set in a wanted distance, and that there in between these two sheets is injected a intervening layer of concrete, which concrete has density less than for normal concrete, preferably less than about 1200 kg/m^3, and that the intervening layer of concrete thereafter is allowed to cure. A preferred embodiment of this comprises before the injection of the concrete, that an open channel element is attached to at least one edge of the element in the centre portions of the aperture between the two metal plates.

In the further description the invention will be explained with detailed examples and with reference to the accompanying drawings where;

Fig. 1 shows a vessel built with parts in a layered structure in accordance with the invention where part of the hull are removed to show the invention,

Fig. 2 shows details of the vessel in fig. 1,

Fig. 3 a-c shows cross-sections of three different embodiments of a vessel where the layered structure in accordance with the inventions is used for whole or part of the vessel,

Fig. 4 shows the layered structure in accordance with the invention,

Fig. 5 shows a second embodiment of the layered structure in accordance with the invention,

Fig. 6 shows a third embodiment of the layered structure in accordance with the invention,

Fig. 7 and 8 shows different embodiments of an element in accordance with the invention,

Fig. 9 shows part of a layered structure module,

Fig. 10 a-d shows different embodiments of dowels used in the invention,

Fig. 11 a-d shows different embodiments of connectors used in the invention.

Fig. 1 and fig. 2 shows a vessel 1 where parts of the vessel 1 are constructed with a layered structure 2 in accordance with the invention. Part of the hull 6, parts of the deck 20 and some hatches 21 are removed to show the layered structure 2 used in the hull 6, the bulkheads 7, the wing tanks 9, and the hopper tanks 8. The hull 6 and the bulkheads 7 of the vessel 1 are designed with a layered structure 2 comprising two metal sheets 3 and a intervening concrete layer 4. One side of the wing tanks 9 and the hopper tanks 8 are design with a metal plate. It is to be noted that wing tanks and hopper tanks may be required for functional reasons, but are not necessary as a structural component of ships designed according to the invention.

As shown in fig. 2 the main structure of the ship comprises the layered structure in the vertical directed parts of the hull 6 and the bulkheads 7, plate girders 12 that extends in a vertical direction. The bottom part of the hull 6, have a layered structure comprising plate girders 12 in the longitudinal direction of the vessel and closed channel elements 13, which together with the girders 12, form spar-boxes 14.

The fig. 3a-c shows three different possible cross sections for a hull where the whole or parts are formed with a layered structure in accordance with the invention. In fig. 3a are all main parts of the hull 6, also the internal wall of the hopper tanks 8 and the wing tanks 9, formed with a layered structure. As one can se in fig. 3a's two bubbles there are at least two possible layered structures that may be used in the hull, for instance a structure of two metal sheets 3 and a concrete layer 4 with or without channel elements 13. These two different structures may be used for hole or part of the hulls shown in fig. 3a-c

In fig. 3b is the inner separation wall of the wing tanks 9 and the hopper tanks 8 made with ordinary metal sheets. In fig. 3c have the hull 6 comprising a layered structure, got a more rounded shape and there are no hopper- or wing tanks, since there is no need for these with respect to structural strength.

Fig. 4 is a principal sketch of the layered structure in accordance with the invention, with the two metal sheets 3 and the concrete layer 4. In fig. 5 is it shown principally a second embodiment where one of the metal sheets 3 have gotten an outer layer 5 of a different material. This might be a solution if for instance the cargo that is to be transported is highly corrosive with the basic metal in the metal sheet 3. These figures are not at all to scale. To illustrate typical dimensions one can mention one example for a layered hull structure, where the outer metal sheet 3 would have a thickness of between 5-25 mm and the metal sheet forming a channel element 13 embedded in the concrete layer 4 would have a thickness of between 5-10 mm.

In fig. 6 is it shown a cross section of a layered structure 2 where there are channel elements 13 embedded in the concrete layer. These channel elements forms with other parts of the layered structure spar-boxes 14.

Fig. 7 and fig. 8 show two different embodiments of elements that, when mounted together form a layered structure. These elements have the same thickness as the layered structure and generally the same length as one of the directions of a layered structure module, and a part of the opposite direction of the layered structure module. The elements comprise two metal sheets 3 and a concrete layer 4. Preferred embodiments comprises also open channel elements 14 between the two metal sheets, and possibly as shown in fig. 8 also closed channel elements 13 embedded in the concrete layer 4. The channel elements are positioned in the aperture between the two metal sheets 3 with spacers 15.

A layered structure wall is comprised as shown in fig. 9 of two metal sheets 3 with a concrete layer 4 in between. The two metal sheets are connected to each other via point connectors 11 and plate girders 12. The concrete layer may comprise embedded channel elements 13 that, together with the plate girders 12, form spar-boxes 14. The channel elements are connected to the sheets with spacers 15.

The layered structure in accordance with the invention may be adapted in many ways to fit in with the requirements in the special use for the layered structure, for instance may the spar-boxes be made of a size suitable for functioning as storage tanks for fuel or ballast water.

Fig. 10 shows some examples of dowels that may be attached to the side of the metal sheet side that faces the concrete layer, thereby improving the bonding and mechanical attachment between the two materials. Fig. 10a shows a knob made of concrete, plastic or other material which is at least as strong as the conrete layer and which is glued to the metal sheet. Fig. 10b shows a simple steel stud which is attached to the metal sheet by way of arc or friction welding. Fig. 10c shows a stud or short channel section which is welded to the metal sheet and provides improved anchorage by way of a bent or protruded form. Fig. 10d shows a similar dowel of length corresponding exactly to the desired metal sheet distance, thereby serving both as anchorage and a practical spacer for the layered structure assembly.

Fig. 11 shows some examples of connectors that bind the two metal sheets in the layered structure together at desired distance and that also provide mechanical interaction with the concrete layer. In addition, such fixed connectors are important for preventing skin buckling in case of poor bonding between concrete and metal sheets. In fig. 11a an I-form connector of steel or another material, is welded to the two metal sheets. Fig. 11b shows a similar case where the welded connector has a U-shape or open channel form. The connector in fig. 11c is different in the sense

that it is welded only to one sheet whereas it becomes attached to the other sheet through an "eye" which is a steel piece with a suitable opening for the connector and which is welded to the opposing sheet. In this way the two sheets get bound together when the opposing sheet is slid into correct position during assembly, see arrow A. The connector in fig. 11d is a double-sided version of the slide connector in which both sheets have "eye" attachments located at opposite positions. The outer sheets become locked into position when an open channel or U-shaped connector is slid into the two "eyes", see arrow B.

The invention has above in part been explained with examples. The scope of the invention should in no way be limited to this but incorporates different modifications and possibilities that are covered by the enclosed claims.

CLAIMS

1. Marine vessel, such as ships, floating platform etc, where the whole or part(s) comprises a layered structure including two substantially parallel metal sheets with a concrete layer in between, where the concrete has density significantly less than that of normal concrete, preferably less than about 1200 kg/m^3, where the layered structure is dimensioned as if the concrete layer in the structure carries substantially no tension but is capable of carrying compressive forces and support the metal sheets.

2. Layered structure for use in marine vessels, such as ships, floating platforms etc, comprising two substantially parallel metal sheets with a concrete layer in between, where the concrete has weight of less than for normal concrete, preferably less than 1200 kg/m^3.

3. Marine vessel or layered structure in accordance with claim 1 or 2, wherein the metal sheets on the surface faced towards the concrete layer comprises means to increase the bonding or connecting properties between the metal sheets and the concrete layer.

4. Marine vessel or layered structure in accordance with claims 1 or 2, wherein the means to increase the bonding properties are an increased roughness in the surface of the metal sheets, or an added adhesive layer or dowels or a combination of these.

5. Marine vessel or layered structure in accordance with claim 4, wherein the dowels reaches a substantial distance into the concrete layer, and at most to the metal sheet on the opposite side of the layered structure.

6. Marine vessel or layered structure in accordance with claims 1 or 2, wherein there in the concrete layer in the layered structure are added fibres to enhance the concrete layer's ductility, reduction of crack openings, and capability for carrying tension forces.

7. Marine vessel or layered structure in accordance with claims 1 or 2, wherein there between the two metal sheets is at least one connector.

8. Marine vessel or layered structure in accordance with claim 7, wherein the connector comprises a point connection.

9. Marine vessel or layered structure in accordance with claims 7 or 8, wherein the connectors comprises girders in at least one direction.

10. Marine vessel or layered structure in accordance with one of the proceeding claims, wherein the concrete layer comprises a plurality of longitudinal substantially parallel load carrying channel elements with equal or different cross sections and with an internal void, which may, together with other elements in the layered structure, form spar-boxes.

11. Marine vessel or layered structure in accordance with claim 10, wherein the channel elements are connected to the adjacent metal sheets with spacers.

12. Marine vessel or layered structure in accordance with claims 10 or 11, wherein both open ends of channel elements are joined with girders with longitudinal direction transverse to the channel element's longitudinal direction and form closed spar-boxes.

13. Marine vessel in accordance with claim 12, wherein there is access to at least one of the spar-boxes in the layered structure, and the spar-box may function as a service shaft and/or inspection shaft or similar.

14. Marine vessel in accordance with claim 13, wherein there is access to the spar-boxes in the concrete layer in a bulkhead so that the spar-boxes may function as compartments for instance for ballast water.

15. Marine vessel in accordance with claim 12, wherein there is access to the spar-boxes in the concrete layer in the layered structure, so that the spar-boxes may function as compartments for fuel.

16. Marine vessel or layered structure in accordance with one of the preceding claims, wherein one or both of the surfaces of the metal sheets faced away from the concrete layer or the inside of a spar-box may include another outer layer of a different material.

17. Layered structure module for use in for instance a vessel such as a ship, a floating platform or similar or other structural constructions, in accordance with the layered structure in claims 2-12, wherein the module is constructed of at least two smaller elements comprising two metal sheets and a concrete layer, where the smaller element a thickness mainly equal to the modules thickness, and that the elements in addition may comprise at least one connector between the two metal sheets so that two smaller elements when put together form two outer smooth metal surfaces.

18. Element for obtaining a layered structural module, including two substantially parallel metal sheets with a concrete layer in between, where the concrete has density less than for normal concrete, preferably less than about 1200 kg/m^3.

19. Element in accordance with claim 18, wherein the element has a length, a width and a thickness, where the thickness and length mainly corresponds to the layered structure module and the width amount to a part of the layered structural module.

20. Element in accordance with one of the claims 18 or 19, wherein the element at least on one edge has a open channel element in the concrete layer, mainly parallel to the metal sheets, which channel element forms at least a part of a closed channel element in the concrete layer, when two elements are joined together.

21. Method for producing a layered structure for building of whole or parts of a vessel such as ships, floating platform or similar, wherein it is used two mainly parallel metal sheets, where the metal sheets are positioned in a wanted distance, and that in between these two sheets is injected an intervening layer of concrete,

which concrete has a density less than for normal concrete, preferably less than about 1200 kg/m^3.

22. Method for producing an element for forming a layered structure for building of whole or parts of a marine vessel, such as ships, platforms or similar, wherein it is used two mainly parallel metal sheets, where the metal sheets are set in a wanted distance, and that there in between these two sheets is injected a intervening layer of concrete, which concrete has density less than for normal concrete, preferably less than about 1200 kg/m^3, and that the intervening layer of concrete thereafter is allowed to cure.

23. Method in accordance with claim 22, wherein before the injection of the concrete, an open channel element is attached to at least one edge of the element in the centre portions of the aperture between the two metal plates.

24. Vessel, structure, structure module and element as described in the specifications and drawings.

ABSTRACT

The invention relates to a marine vessel, such as ships, floating platform etc, where the whole or part(s) comprises a layered structure and a layered structure for use in vessels, including two substantially parallel metal sheets with a concrete layer in between, where the concrete has density significantly less than that of normal concrete, preferably less than about 1200 kg/m^3, where the layered structure is dimensioned as if the concrete layer in the structure carries substantially no tension but is capable of carrying compressive forces and support the metal sheets. The invention also includes a layered structure module, elements for building a module, and methods for producing a layered structure according to the invention.

Fig. 1

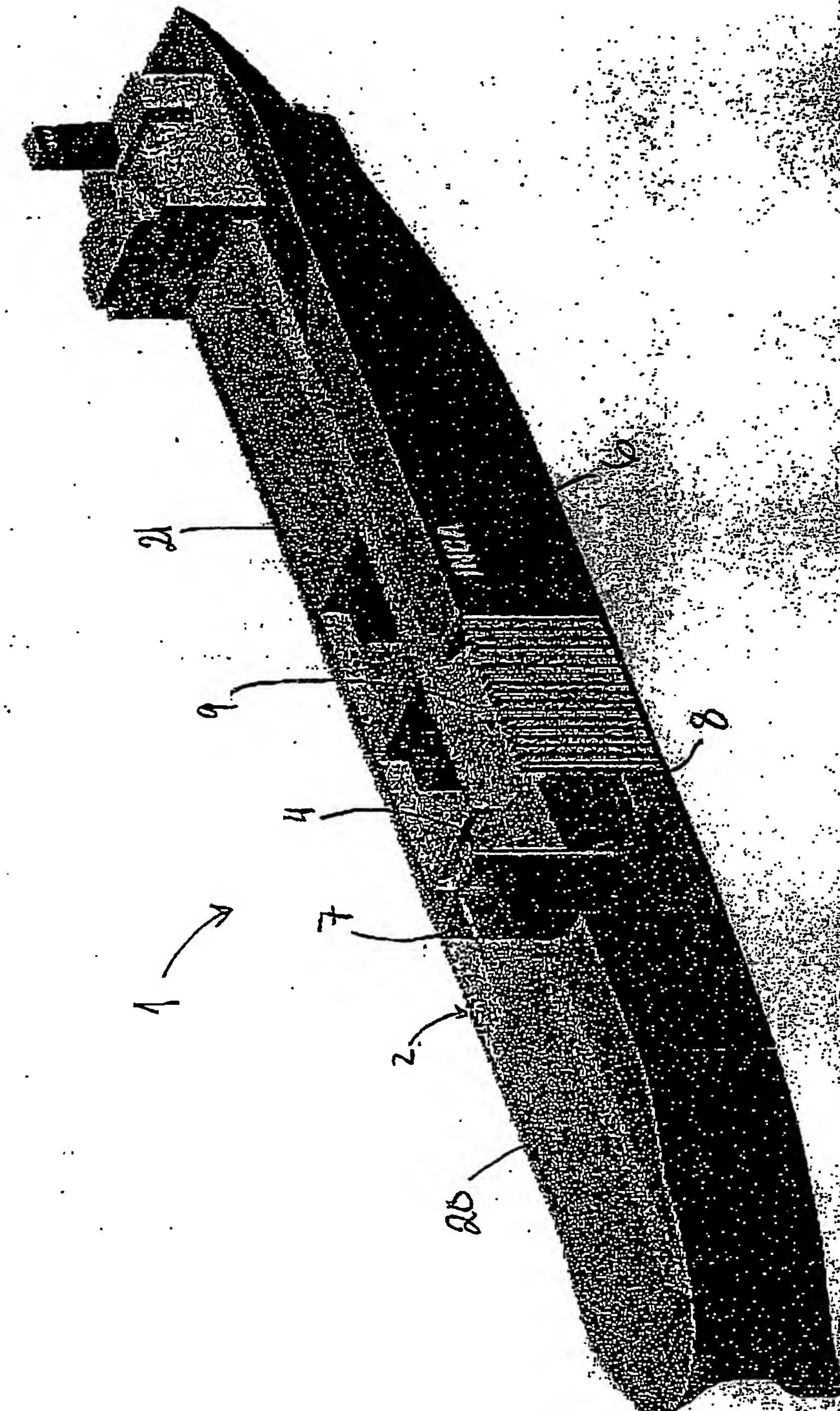


Fig 1

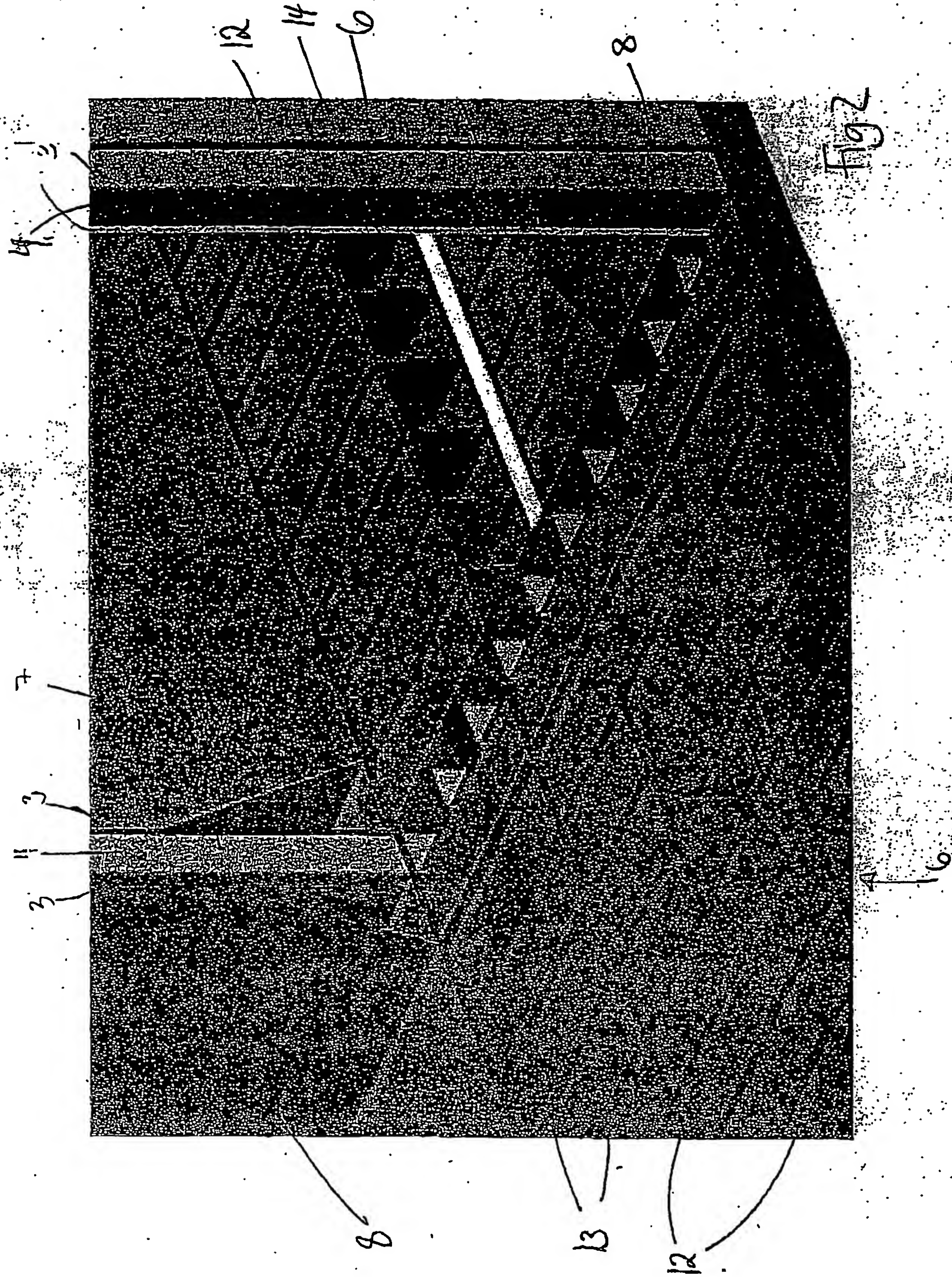


Fig 2

Fig3a

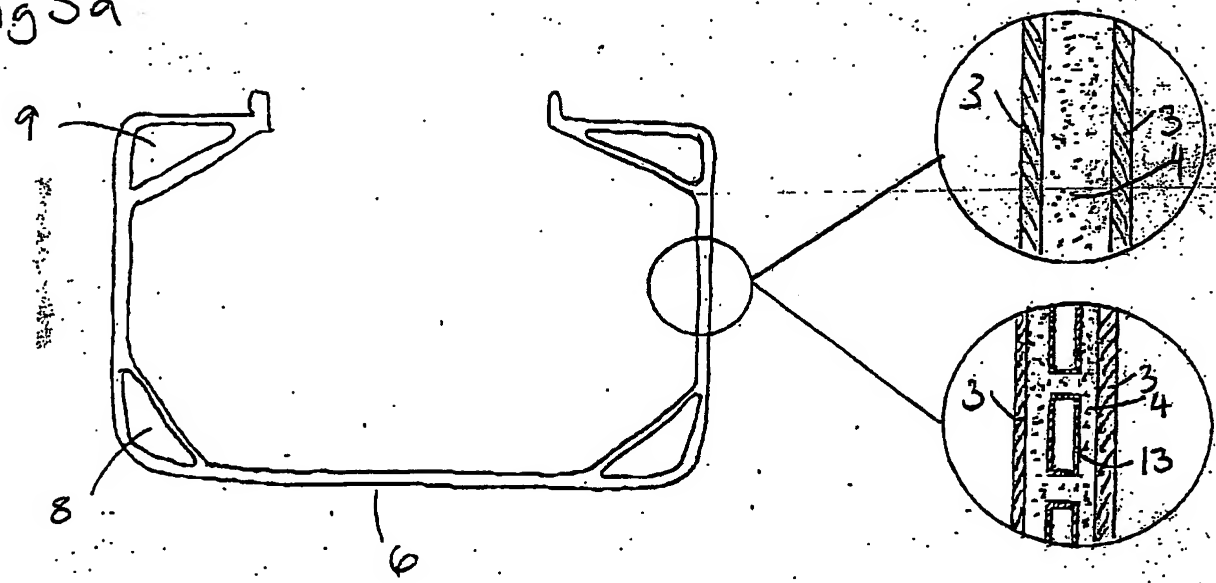


Fig3b

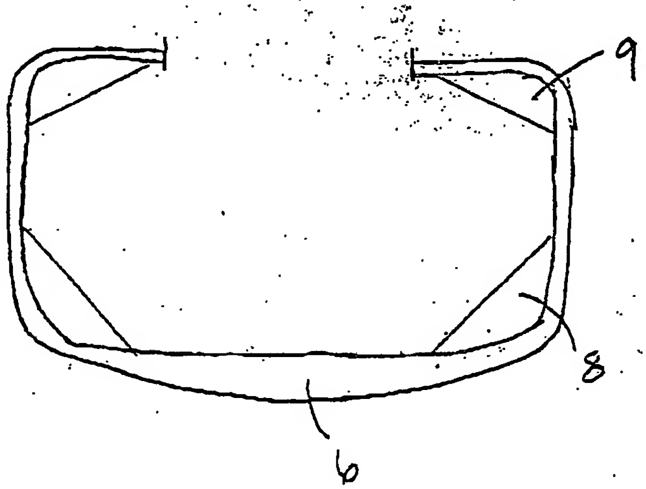
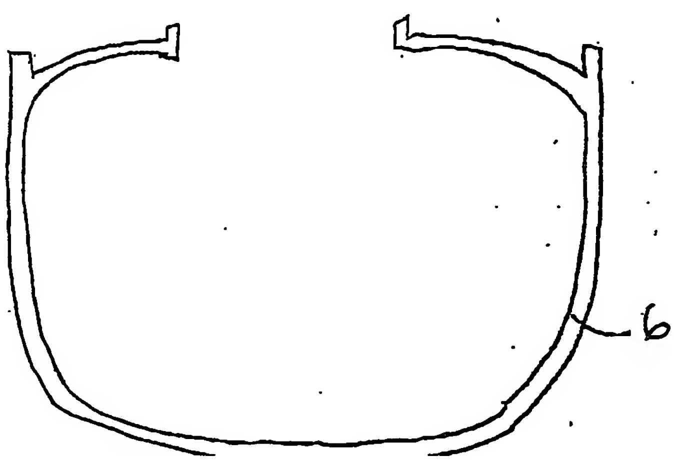


Fig3c



C

Fig 4

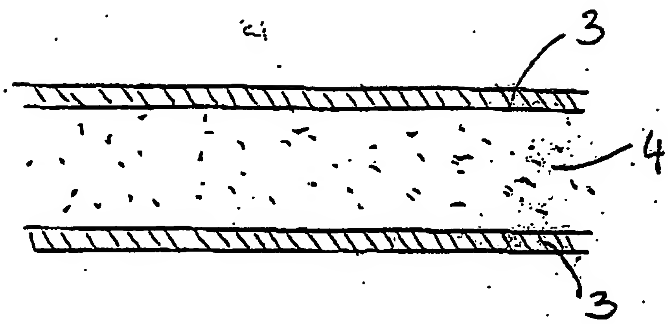


Fig 5

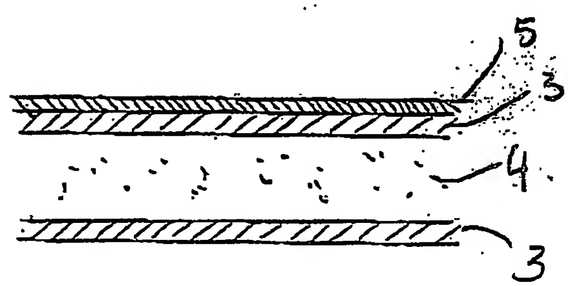


Fig 6

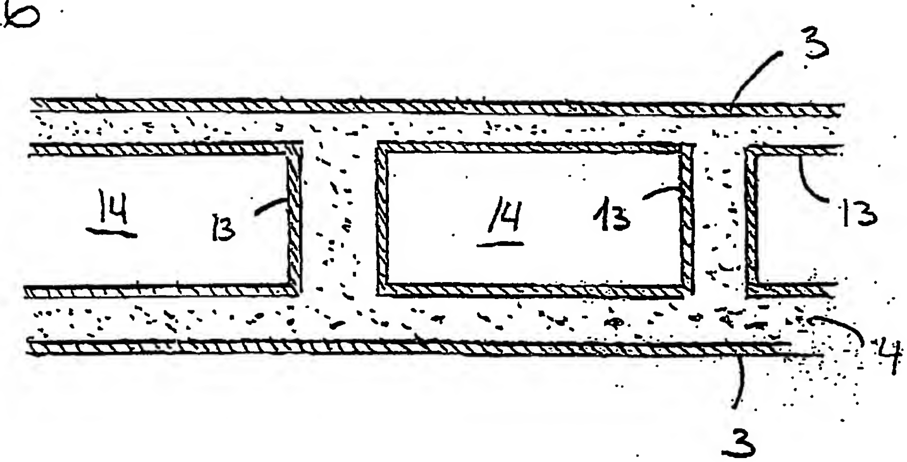
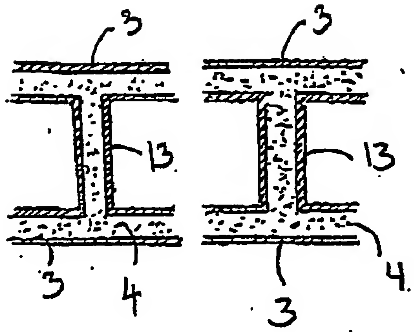


Fig 7



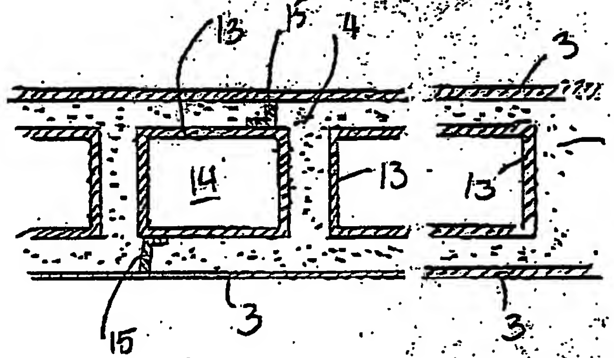
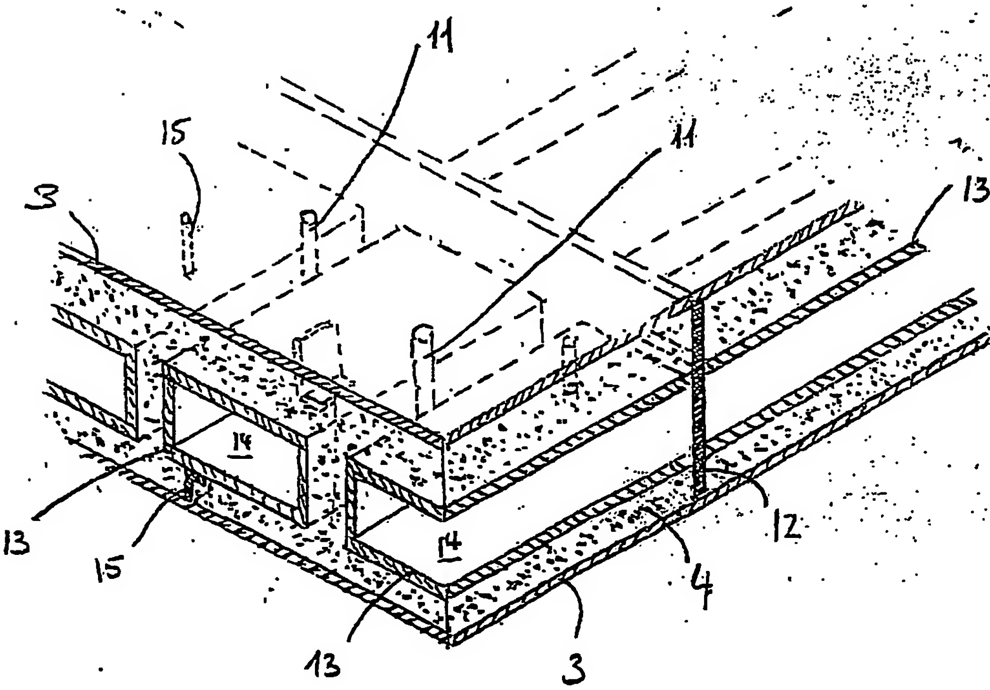


Fig 8

Fig 9



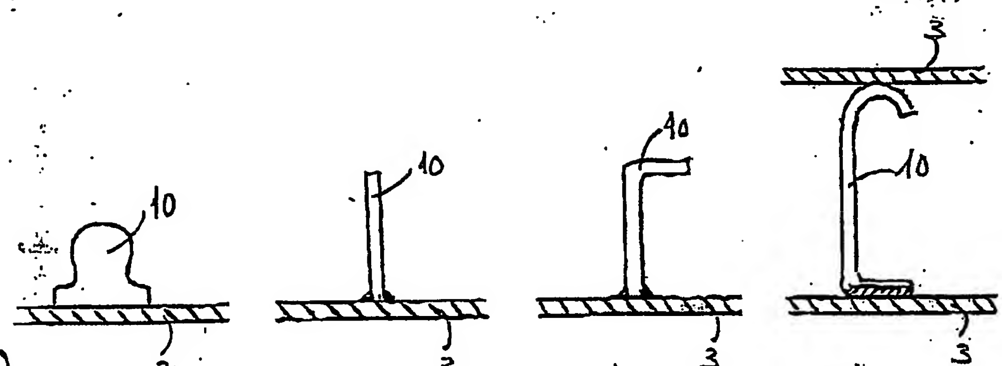


Fig.10 a) b) c) d)

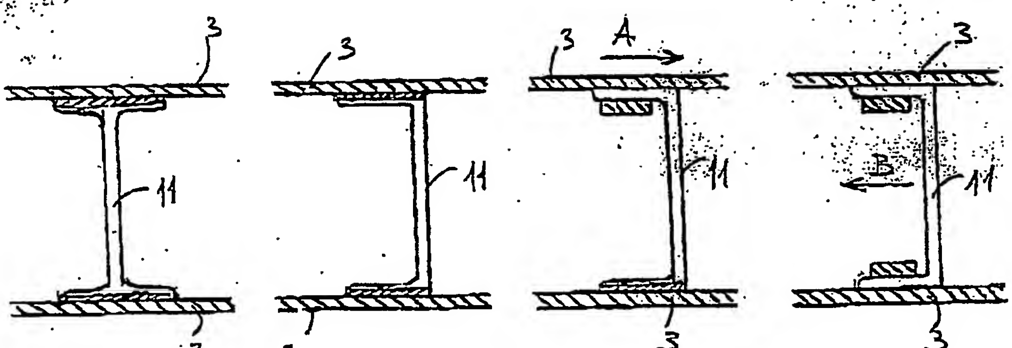


Fig 11 a) b) c) d)

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